Potential Influence of Land Development on Temperature in the Central Florida Region

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Justification

According to the PennDesign study *(Barnett, J. et al., 2005)*, the population of Brevard, Lake, Orange, Osceola, Polk, Seminole and Volusia Counties will have increased by 4.2 million people by 2050. With the current sub-urban land development growth policies, 1,163,573 acres of land will need to become urbanized to accommodate the new population.

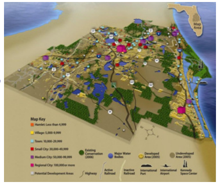

Fig. 1: Central Florida today. (courtesy of www.myregion.org)

An alternative land development plan changes the current extremely dispersed and inefficient form of development, which is detrimental to the fragile natural environment, to a higher density development using only 420,410 acres. The alternative urban model, built with buildings, town homes and low-rise apartments, will reduce infrastructure costs that will allow the acquisition of environmentally sensitive land and the transit system needed to support the proposed higher residential densities.

An important question not taken into account in the PennDesign study is how these two land development strategies will affect the regional climate due to the heat island effect (HIE) caused by urban development. HIE will potentially increase temperatures and modify the rainfall patterns in the area, modifying the energy and water needed by the projected cities under both scenarios.

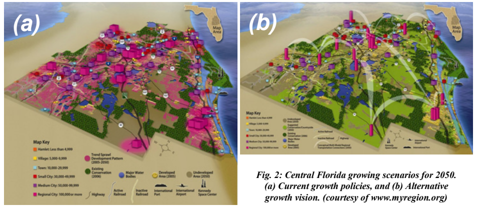

Fig. 2: Central Florida growing scenarios for 2050. (a) Current growth policies, and (b) Alternative growth vision. (courtesy of www.myregion.org)

Objective

- To study the potential impact of both 2050-projected land development strategies on the regional climate.
- To evaluate the feasibility of using numerical climate models to assess those potential impacts in order to provide valuable information to decision makers.

Materials

- The Florida State University/Center for Ocean-Atmospheric Prediction Studies regional spectral model (FSU/COAPS) coupled to the National Center for Atmospheric Research (NCAR) Community Land Model v.2 (CLM2). The coupled model is nested in the FSU/GCM (~200x~200km resolution).
- Land, ocean and atmospheric boundaries and initial conditions from the warmest year in Florida (1998).

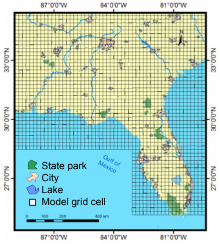

Fig. 3: Current distribution of urban and preserved areas in the Southeast US. The grid indicates the horizontal resolution at which the model performed (~20 x ~20 km)

Methods

1. Energy balance

Two human-related terms are added to the surface energy balance equation *(Taha, 1997; Grimmond and Oke, 1999)*:

$$(1-\alpha)Q_i + L^* - H - \lambda E - G + Q_f - Q_s = 0$$

Where:

α	*Albedo*	H	*Sensible heat flux*	Q_f	*Anthropogenic heat flux*
Q_i	*Incoming solar radiation*	λE	*Latent heat flux*	Q_s	*Storage heat flux*
L^*	*Net long wave radiation*	G	*Non-urban ground heat flux*		

1.1. Anthropogenic heat flux

- Attributed to fuel combustion, air conditioning and other human activities
- Depends on factors such as the intensity of energy use, transportation systems and power generation
- Exhibits both seasonal and hourly variations

1.2. Storage heat flux

- It is the net uptake/release of energy by sensible heat changes in the urban canopy air layer, buildings, vegetation and urban ground
- It is calculated as a function of the net all-wave radiative flux (Q^*) weighted by four urban type areas (A_i): rooftops, impervious, walls and vegetation

$$Q_s = \sum_{i=1}^{4} A_i \left(a_i Q^* + b_i \frac{\partial Q^*}{\partial t} + c_i \right)$$

Where:

a_i, b_i and c_i are empirical coefficients based on the Objective Hysteresis Model (OHS; *Grimmond and Oke, 1999*)

	Urban type area (A_i)			
City type	Rooftops	Impervious	Walls	Vegetation
Urban	32%	25%	42%	1%
Sub-Urban	29%	24%	21%	26%

2. Experiments

1. After including the urban parameterization in the FSU/COAPS/CLM2, a simulation of the heat island effect was evaluated using land surface a) without prescribed urban areas, and (b) with current urban areas.
2. To simulate the effect of both growth development strategies, the FSU/COAPS/CLM2 model was run using both 2050 projected land surfaces.

Results

1. Simulating heat island effect

- Under the warmest conditions of 1998 the HIE produced significant increments in temperatures and evaporation around Tampa and Jacksonville. Due to the highly stable oceanic influence, Miami was less influenced by the HIE.

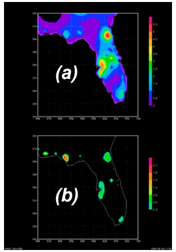

Fig. 4: Simulated differences of (a) minimum temperatures and (b) evaporation between current urban and non-urban land surfaces

2. 2050 growth scenario simulations

- This preliminary results showed that the aggregated effect of highly sparse sub-urban land developments replacing vegetated areas in the Central Florida Region, produced a higher HIE than the one produced by the establishment of high density urban areas.

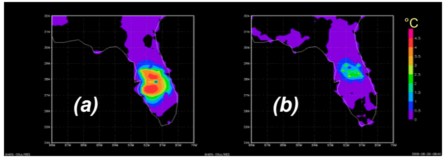

Fig. 5: Simulated Increments in Minimum Temperature: 2050-projected land development for two urban growth scenarios in relation to current conditions (a) current growth policies, and (b) alternative growth vision

- Due to the short simulated period of time, rainfall patterns were not modified; however, there was a significant change in cloudiness patterns. This could potentially produce changes in precipitation.

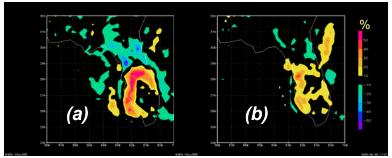

Fig. 6: Simulated cloudiness change: 2050-projected land development for two urban growth scenarios in relation to current conditions (a) current growth policies, and (b) alternative growth vision

Conclusions

- Heat island effect HIE is highly dependent on the geographical position of the city in relation to major water bodies.
- The aggregated effect of large sub-urban areas produced a higher HIE than the one produced by high density urban areas.
- Despite random simulated rainfall patterns, simulated cloudiness did follow an urban footprint.
- These are preliminary results and more simulations at a higher resolution must be performed before using these results.
- Regional Circulation Models are promising tools to support the understanding of land development strategies on the regional climate.

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